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ALSAT -1 FIRST YEAR IN ORBIT

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ABSTRACT

The role of satellites in medium and high-resolution reconnaissance of the Earth has been well demonstrated in recent years through missions such as Landsat, SPOT, IKONOS, EROS, ImageSat and Quickbird. Medium resolution data products have added significantly to Earth science, but commercial markets have concentrated on enhancing resolution. The markets for such high-resolution data products are well served, and are likely to become more competitive with further planned high-resolution missions. The small satellite sector has concentrated on reducing the cost of specialised data products that are ill served by current missions, and on the development of systems providing niche services. One such area where smaller satellites can provide a distinct advantage is in meeting the needs for higher temporal resolution, as this typically requires multiple satellites to operate as a constellation. Such a system has been discussed widely in the disaster monitoring community,
Surrey is currently engaged in launching its first constellation to provide daily global coverage at moderate resolution in three spectral bands, as part of a system to provide global disaster monitoring. The first spacecraft in this Disaster Monitoring Constellation (DMC), ALSAT-1, was launched in late 2002. The programme employs novel models for international collaboration, and demonstrates how small satellite missions can be employed in emerging applications. This paper provides an overview of the DMC programme, details the ALSAT-1 spacecraft and payload, and provides the first in-orbit mission results from ALSAT-1. The paper also addresses the future of the programme, and an update of the second DMC launch due in August 2003. The latest results of the 3rd DMC Consortium meeting will also be reviewed.

1 INTRODUCTION

The launch of ALSAT-1 in November of 2002 saw the first Disaster Monitoring Satellite successfully placed in orbit. The development of the Disaster Monitoring Constellation demonstrates that small satellites can involve a wide range of nations in worthwhile space programmes. Earth Observation missions are particularly well suited to stimulate the development of sustainable resource management and environmental monitoring, and can aid the development of new national industries and space capabilities.

The role of satellites in medium and high-resolution reconnaissance of the Earth has been well demonstrated in recent years through missions such as Landsat, SPOT, IKONOS, EROS, ImageSat, Quickbird, IRS, and various others. Medium resolution data products have added significantly to Earth science, but commercial markets have concentrated on enhancing resolution. The markets for such high-resolution data products are well served, and are likely to become more competitive with further planned high-resolution missions. The small satellite sector has concentrated on reducing the cost of specialised data products that are ill served by current missions, and on the development of systems providing niche services. One such area where smaller satellites can provide a distinct advantage is in meeting the needs for higher temporal resolution by means of an affordable constellation of EO satellites.

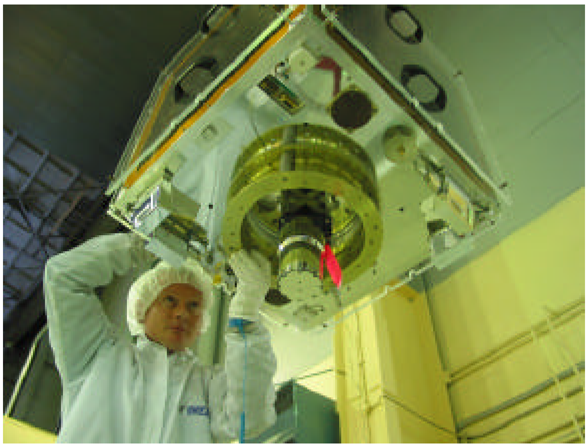

Figure 1 ALSAT-1 Preparing for Launch

The international organisations and communities that consider disaster monitoring and mitigation using space missions have identified many detailed requirements for dedicated missions. Accessibility and high temporal resolution have always been key parameters, but due to the diverse nature of disasters this application was found to require a wide range of sensors, including thermal-IR, multi-spectral and hyper-spectral sensors, high-resolution panchromatic sensors and Synthetic Aperture Radar (SAR). As a result the development of a dedicated disaster monitoring missions has always remained too costly to contemplate, although an international charter on disaster management attempts to coordinate existing in-orbit assets in case of disaster.

In 1996 SSTL proposed to develop a remote sensing constellation [1] based on the emerging Earth Observation capabilities of low cost small satellites, targeting medium-resolution visual observation of stricken areas using multi-spectral instruments. It argued that a constellation of small satellites provides the most affordable and sensible solution to the problem. The proposed system would never address all the complex requirements, but would provide a useful and practical first step in the development of a dedicated disaster monitoring system. The projected cost of the entire constellation would be well within that of a single conventional remote sensing spacecraft. Yet, rather than targeting a single source of funding for the constellation, a novel concept was adapted based on individual ownership of a single spacecraft and ground station pair. This leads to a relatively small investment for each participant, which can be justified on the basis of meeting individual requirements, but in combination with a broad collaboration agreement, it provides owners with absolute control over their own assets to meet specific national or commercial needs, but also strongly encourages owners to share resources to reap the benefits of operating the spacecraft as a constellation. Amongst the benefits is the enhanced temporal resolution, a unique source of data that is not available from other existing space-based assets. The consortium also provides a method of sharing and spreading risk against a launch failure or spacecraft fault. The consortium charter has been deliberately kept simple, but direct provision has been made for directing free use of the constellation in cases of a disaster area being declared by the United Nations.

2 ALSAT-1

The first partner to commit to the DMC with a spacecraft was Algeria through the Centre National Des Techniques Spatiales, a branch of the Ministry of Higher Education and Research based in Arzew, near Oran, in northwest Algeria., Dr Azzeddine Oussedik the Director of CNTS and visionary behind the programme has since become the founding Director General of the Algerian National Space Agency.

CNTS have long been researching instrumentation and applications of space based assets in the national interest. Algeria is the second largest country in Africa, and has a huge land are from the sparsely populated desert regions in the south to the greener more citied areas in the north on the Mediterranean coastal margin. Monitoring of environmental resources and desertification along with pollution and urbanisation is of great importance. Also, as recent tragic events have highlighted, Algeria is also prone to devastating seismic events. These factors, coupled with a desire to cooperate internationally and benefit regional monitoring applications fitted with the DMC requirements well. CNTS is developing the Algerian national space capability, and is expanding to new premises and plans to build significant parts of their next spacecraft in Algeria. ALSAT-1 was constructed during a two year Know How Transfer and Training Programme at SSTL.

3 DMC CONSORTIUM

In 2000, soon after the Centre National des Techniques Spatiales (CNTS) signed up as the anchor tenant for the constellation, partnering a second satellite funded by the British National Space Agency under the MOSAIC small satellite programme the Nigerian Agency for Space Research & Development (NASRDA) agreed to participate. The private Thai Mahanikorn University, and the Turkish Ministry of Science and Technology research institute BILTEN TUBITEK agreed to become an associate members to the DMC consortium introducing their ThaiPaht-2 and BILSAT spacecraft respectively into the constellation.

Most recently, the Chinese Ministry of Science and Technology also agreed to participate in the constellation with an advanced spacecraft carrying both the standard DMC payload, in combination with a high-resolution 4m-GSD panchromatic imager. Additional members are still being considered. In order to address the user needs in the event of a disaster, partners also include Reuters providing access to their AlertNet network for disaster relief, so that data can be requested, coordinated and delivered to humanitarian aid agencies over the Internet. CHEST will provide data into the academic community to exploit further application of the unique high temporal resolution data, and ESYS Ltd. in the UK is examining commercial exploitation of resulting data.

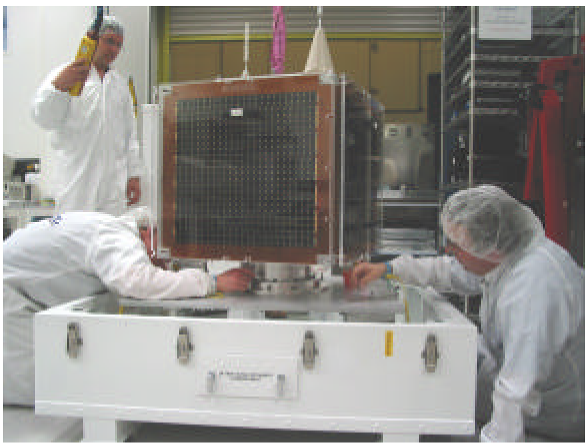

Figure 2 Preparation for the ship-out of ALSAT-1 to the launch site

The first partner meeting was held in 2001 at Surrey, at which the partners agreed to set up a consortium so that maximum benefit can be derived for all partners by working together in a constellation. Basic principles of data sharing were agreed, such that 5% of system capacity could be reserved for disaster management.

At the second consortium meeting in Algeria, a Memorandum Of Understanding was signed by all parties to cover. As it proved difficult for the consortium partners to co-align their national funding schedules, it was also decided to launch the constellation using a series of three launches, in late 2002 for ALSAT-1, mid 2003 for BILSAT-1, NigeriaSAT-1and UK-DMC. A third launch would cover the remaining satellites, although the system would be virtually operational following the second launch. The meeting also resulted in a number of working groups to cover a range of infrastructure designs and developments for the eventual exploitation of the constellation assets.

The third meeting was held in Nigeria in March 2003, where the primary objectives of preparation and planning for the operation of the full DMC following the second launch were discussed. Following the experience gained on the first launch, orbital parameters were agreed for the second launch to insert the three new spacecraft into the constellation. The Consortium also reviewed the ALSAT-1 mission and its preliminary EO data. And further discussions were held on data sharing, exploitation and continuing international collaboration

4 CONSTELLATION DESIGN

The primary driver for the system design has been to put a baseline conceptual system into operation within a reasonable time, rather than to capture the full set of requirements from the onset of the project.

The requirements for the DMC have been derived by examining the use of LandSat imagery in times of disaster, leading to a choice of instrument compatible with LandSat bands 2,3 and 4 (near Infra-red, Red and Green). Such remotely sensed data is used widely. Applications include the observation and evolution of both natural and man-made disasters, including those of storm, tides, earthquakes, forest and grass fires, vegetation health, flood, drought, pollution and contamination. Users of imagery currently available complain that they do not have regular and timely access, and that response time is often inadequate for serious use. The aim of the DMC is therefore to provide the ability to revisit and return imagery from any part of the globe, on a daily basis. A system design goal is also to provide a high degree of responsiveness, both in tasking the constellation and image delivery.

In order to improve the chances of success, a modest number of spacecraft and owners were desirable. This would keep allow the use of a single dedicated launcher, solving a key risk area in small satellite systems As a consequence, the constellation design would need to be based on a single orbit plane. In further trading the constellation requirements with spacecraft capabilities, a set of basic system parameters was derived.

A sun-synchronous orbit is base lined with a Local Time of the Ascending Node at 10:00 near 700km altitude. With a moderate Ground Sampling Distance of 32m, it is possible to provide daily global coverage at the equator with 4 to 8 spacecraft, and each spacecraft would need to be able to access 300 to 600km of swath. The system design lifetime was set at 5 years.

5 ALSAT-1 SPACECRAFT DESIGN

Based on the original mission concept, ALSAT-1, the first DMC spacecraft was designed manufactured and tested ready for ship-out to the launch site in 24 months. The remaining spacecraft were manufactured to the same reference design, but staged behind by several months. Both ALSAT-1 and NigeriaSAT-1were part of Know-How and Technology Transfer programmes run at SSTL where engineers with contemporary training and skills come to Surrey to turn their experience to the particularities of working with spacecraft

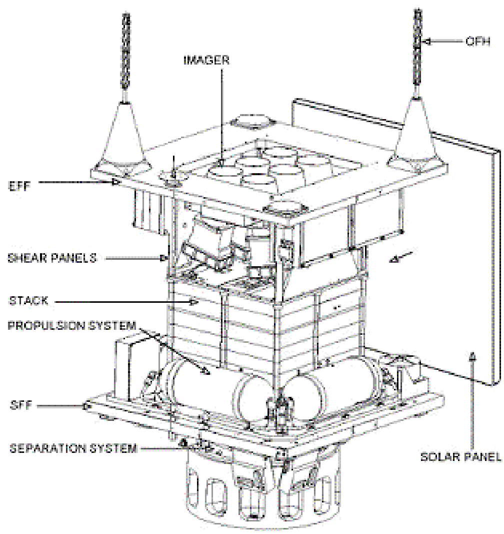

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Figure 3 DMC-1 Spacecraft

A key decision in the spacecraft design was to reject a 3-axis controlled solution with instrument off-pointing capability, for a nadir-stabilised platform with a wide swath instrument and electronics off pointing.

The following description is for the standard DMC spacecraft. BILSAT-1, which will become part of the initial constellation, is a far more complex design and is described more fully in reference [2].

6 ALSAT-1 AND DMC PAYLOAD

The Earth Observation payload operates in Store and Forward mode, so that images can be taken out of range from any control stations. Payload data remains stored on-board until the spacecraft is commanded to return the data once in contact with one of the network ground stations. The payload therefore comprises two banks of cameras, a set of solid-state data recorders, and two high-speed downlinks. As with most small satellites, a balance has been struck between cost and performance. Payload operations are fundamentally resource limited by the on-board power available at the end-of-life, and on-board storage. Fundamentally, the system design constrains the spacecraft on every orbit to

1. Take images filling half its data recorders
2. Return all this data to a single station

In practice, the system is well balanced between these constraints, and there are cases where any of these becomes the limiting factor. Data storage becomes the limiting factor when the spacecraft does not transit stations on several successive orbits, and power is the limiting factor when the spacecraft transits several stations in a single orbit.

The imager comprises six lens and sensor pairs, configured in two banks as part of an overall optical bench assembly. The banks are mounted angled away from nadir by approximately 12º, to double the swath width, but with a small overlap of approximately 5% to aid image stitching. The Field of View from each bank is 26.6º.

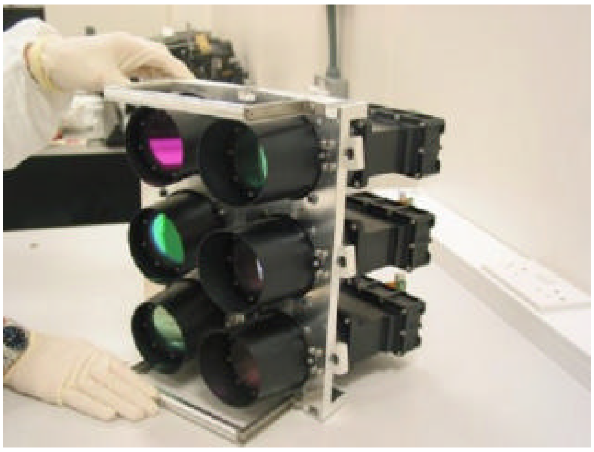

Figure 4 DMC optical assembly and sensor assembly

Each imager includes a customised Kodak linear CCD sensor with over 10,000 pixels measuring 7x7µm each, providing 32m Ground Sampling Distance at nadir. A Schneider lens is employed providing a wide focal plane, and each lens and sensor is integrated into an optical assembly with its own individual spectral filter. The complete instrument provides near 20,000 pixels in the standard LANDSAT bands 2,3 and 4 (Green: 0.52µm to 0.62µm, Red: 0.63µm to 0.69µm and Near Infra-Red: 0.76µm to 0.9µm).

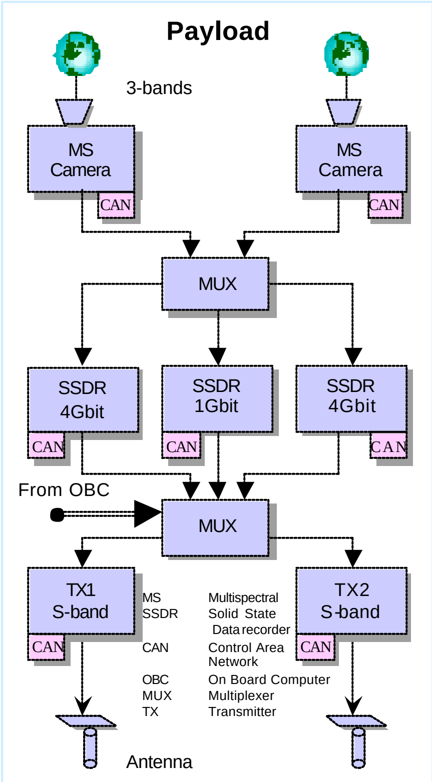

Figure 5 DMC-1 payload data handling

The two main solid-state data recorders are configured to provide 4Gbit each, and a back-up data recorder provides an additional 1Gbit of solid-state storage. Software windowing functions are employed allowing the whole, or only sections of the full swath to be stored. Each instrument bank is cross-connected to the data recorders in a redundant fashion, and third functionally redundant 1Gbit data recorder. Each half of the instrument can be powered separately, which allows flexible management of the on-board power resources. Input from the spacecraft clock allows software on the data recorder to deal with significant parts of the payload scheduling task.

The primary data recorders are based around a Motorola PowerPC processor, and have the capability to carry out on-board image processing should this be required in future. The secondary data recorder is based on an Intel StrongArm processor, providing a minimal level of redundancy through alternate technology.

A high speed S-band downlink is employed for data return, with 4W RF power, and operating at 8Mbps. QPSK modulation is used, with half rate convolutional coding. A quadrifilar helix antenna is employed, providing a circularly polarised, shaped omni-directional pattern, with equal power flux density across the entire footprint.

7 DATA PRODUCTS

Various imaging modes are possible. The accessible swath width by the payload is over 660km from 686km orbit when using both halves of the payload.

In order to manage the size of the data products, images are split into "tiles" of 2500x2500 pixels each (approximately 80x80km) in all three spectral bands. Various parameters are stored with each image, including spacecraft position, attitude and attitude rate. Typically, for dynamic Earth Observation only a few image tiles will be selected for regular observation, and up to 24 image tiles can be supported during a single image take every orbit. Providing sufficient power is available, up to 48 tiles can be accommodated in memory as depicted in Figure 6.

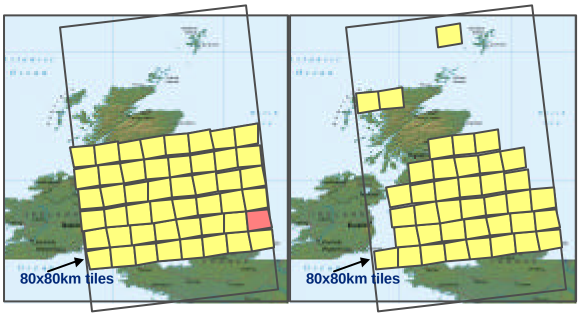

Figure 6 DMC tiling

A further imaging mode is possible as illustrated in Figure 7, which allows very wide swath images to be acquired within very short time-spans of one or several orbits. For instance, four satellites can gather four adjacent image strips within 75 minutes, covering over 2500x560km.

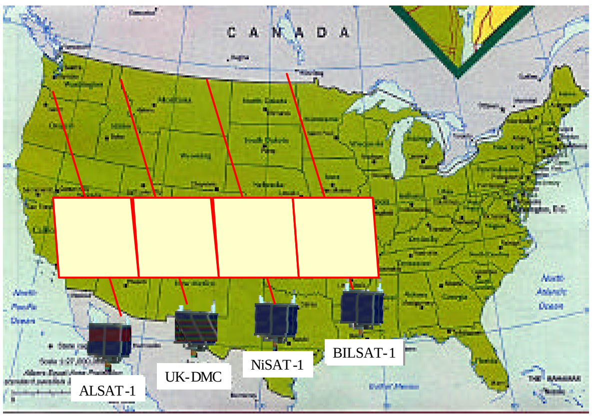

Figure 7 Adjacent swaths capability

The ability to continue extending the swath in longitude then depends solely on ground station placement and capacity. Basic pre-launch radiometric and geometric characterisation has been performed, and it is anticipated both raw data products, as well as radiometrically and geometrically corrected products will be available.

8 ALSAT-1 SPACECRAFT PLATFORM

The platform design for the DMC spacecraft is an enhanced micro satellite measuring 640x640x680mm. The spacecraft weighs 88kg, of which 19kg is payload. The spacecraft is cubical in shape with four body-mounted panels, with the remaining sides including the spacecraft launch adaptor, sensors, payload apertures and antennas. The structure is based on Aluminium and Aluminium Honeycomb panels, and has been designed to be compatible with a wide range of launchers, and includes a stack of "MicroTray"modules traditionally used by SSTL on all its micro satellites [3]. A number of "NanoTrays" with heritage from the SNAP nano satellite [4] are also carried. The stack of trays carries an optical platform, and between the stack and the panels the battery, wheels and propulsion system are carried. The spacecraft employs a fully passive thermal control system.

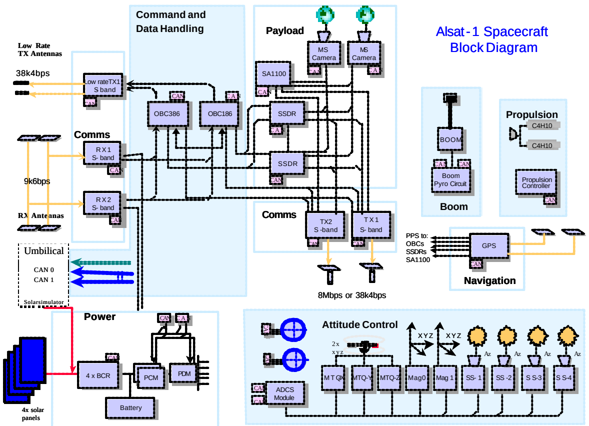

Figure 8 ALSAT-1System Block Diagram

A system block diagram is shown in Figure 8. The spacecraft is largely dual redundant, with a CAN-based data handling system.

A propulsion system is required in order for the spacecraft to be able to operate as part of the constellation, and is used to carry out initial launcher injection corrections, spacecraft separation into their respective orbital slots, altitude maintenance and finally an end-of-life manoeuvre to remove the spacecraft from the operational system. The system does not offer provision for maintenance of the Local Time of the Ascending Node (LTAN), and instead the initial altitude and inclination are selected to minimise the LTAN drift over the mission lifetime.

A Butane based monopropellant system was selected, as it provides a high density Isp, allowing lower volume tanks to be used when compared with a conventional Nitrogen system. A further advantage is that the storage pressure is much lower, reducing the shipping and safety concerns.

The propulsion system delivers approximately 20m/s delta-vee., and comprises 2 cylindrical tanks holding 2.3kg of propellant, and a single low-thrust thruster augmented by a small resistojet to boost its efficiency. The system is designed as "V"-shape onto the spacecraft base-plate, alongside the propulsion-controller electronics.

As mission lifetime and reliability were considered key parameters, a momentum biased attitude control system was selected, augmented by a gravity gradient boom. This provides natural platform stability, as well as providing an inherently safe spacecraft attitude configuration.

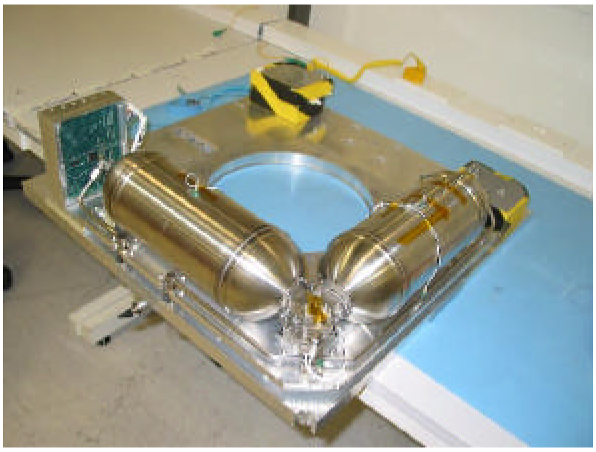

Figure 9 ALSAT-1 propulsion system

The spacecraft is 3-axis stabilised, using a pitch momentum wheel and yaw reaction wheel, and dual redundant 3-axis magnetorquers. The instrument swath width is wide and so accurate pointing or no roll slewing is required. A gravity gradient boom is employed to provide a high degree of platform stability, constraining attitude rates to less than ±2.5mdeg/s. Two vector magnetometers and four dual-axis sun-sensors are carried in order to locate position to better than ±0.25°, but control is relaxed at ±1°. A GPS receiver is carried to aid navigation during the critical mission phases, and also provides an accurate spacecraft clock.

The power system comprises four body mounted GaAs solar panels and an 8Ah NiCd battery. A raw 28V bus is distributed, alongside a regulated 5V bus. Lines are electronically switched and over-current protected with electronic switches. The system delivers over 30W orbit average to the platform and payloads, with 12W for the platform, and approximately 16-20W available for payload operations.

The telemetry and telecommand system employs S-band with a dual redundant CPFSK 9.6kbps uplink, and a single 38.4kbps QPSK downlink, with redundancy provided by the two payload downlinks. The uplink employs patch antennas, whereas the downlink employs a simple monopole antenna. The data handling system employs a dual redundant Control Area Network (CAN) bus for distribution of telemetry and telecommands, as well as small file transfers and bootloading. Two functionally redundant on-board processors are carried. The OBC186 is used for housekeeping, and an OBC386 for attitude control.

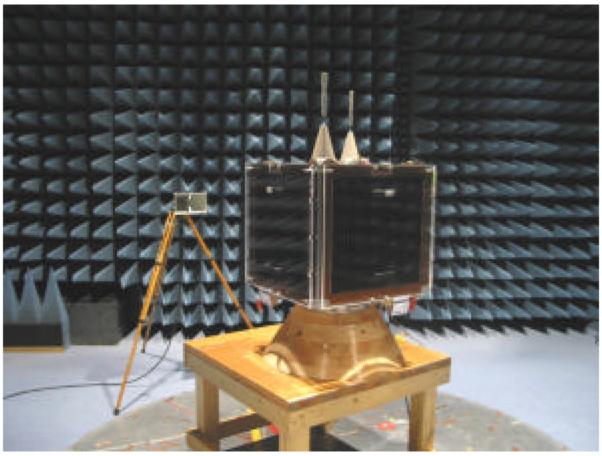

Figure 10 ALSAT-1 at EMC Testing

The DMC spacecraft are designed to be operated using IP-based protocols for all routine operations, as pioneered on UoSAT-12 [5]. The payload downlink also implements the new CCSDS File Delivery Protocol over IP on the 8Mbps payload downlink.

9 GROUNDSEGMENT

The DMC is designed to operate with a distributed ground segment, which provides greatest redundancy, ample scope for growth, and encourages cooperation. It can also be operated as a centralised system when necessary, for instance to carry out constellation-wide housekeeping tasks.

Figure 11 DMC 3.7m tracking S-band dish antenna at Centre National des Techniques Spatiales, Arzew, Algeria

The station is based on a 3.7m tracking dish, which includes both S-band TT&C as well as the S-band high-speed payload downlink. It exhibits a G/T of 13dB/K at elevation angles above 10 degrees, and includes an X-over-Y rotor drive so that it does not have any dead zones overhead.

Each participant owns at least one station to access the constellation assets, and maintains the operations schedule and resourcing for its own spacecraft. Each station includes Mission Planning System software, a Data Archive and catalogue, and basic image processing capabilities.

System users can request targets via an internet-based user interface. The scheduling software identifies imaging opportunities on all DMC satellites based on spacecraft resource modelling, and provides feedback based on the various opportunities identified. The operator may then send a request to that partner satellite, which will appear in the partner's scheduling system. If accepted it will then be uploaded to the satellite and acquired.

A second mode is planned for disaster response. Reuters AlertNet will receive requests for images from Aid agencies, activated by the country affected by the disaster asking for international assistance. The DMC consortium will then target the disaster response images with highest priority, and upload a schedule to all available satellites in the constellation.

Since the satellite tasking system is designed to enable disaster requests to be centrally scheduled, this also provides the basis for scheduling of commercial orders. The DMC constellation working in synergy can double the number of images acquired and downloaded in comparison with the sum of the individual satellites. This is because there are considerable more download opportunities to the network of DMC ground stations, which frees the storage capacity of the SSDR for more images.

The DMC capacity will primarily be used to fulfil national EO requirements, such as land use mapping, urban development monitoring etc. However the capacity of the system is expected to enable imaging to be carried out commercially, thus meeting the demand for high time resolution imaging in various application areas.

Stations have so far been installed in the UK at SSTL, in Algeria at Arzew, and in Nigeria at Abuja, and are inter-connected via the Internet. This allows remote control and data collection where desirable, but most importantly allows for distributed payload management, which can eventually lead to improved system responsiveness. The Mission Planning system is designed to be cooperative, with the assumption that each spacecraft will nominally be operated from its corresponding station. Requests for commanding the platform or payload from other users will be received over Internet, and reviewed by the spacecraft owner against its own priorities. Commands for disaster monitoring support will be pre-approved and will have the highest priority. It is anticipated that these man-in-the loop systems will eventually be replaced with software proxies to reduce the system response time. Surrey staff will initially carry out constellation management tasks from its UK station.

Only full collaboration leads to the benefits of daily global access to a particular location. Consortium members are free to negotiate full use of the constellation assets with their peers, for instance by using 25% of the constellation for 100% of the time, or 100% of the constellation for 25% of the time.

10 LAUNCH

The first spacecraft in the constellation, ALSAT-1, was launched on the 28th November 2002 on a COMOS-3M launcher. A second launch is planned to bring the constellation into full operation with a total of four spacecraft, by adding NigeriaSAT-1, UK-DMC and BILSAT-1

Figure 12 ALSAT-1 Launch on Cosmos-3M from Plesetsk Cosmodrome.

. Spacecraft will be equally spaced along the orbit, and the constellation is planned to operate at an initial Local Time of the Ascending Node of 10:00am, which will initially drift to 11:00am, before returning to 10:00 after 5 years. Additional partner spacecraft can be added subsequently, to increase the temporal coverage or provide replacement spacecraft.

11 COMMISSIONING

Following ALSAT-1's successful separation from the launch vehicle and deployment into orbit, the spacecraft platform was rapidly commissioned from the CNTS ground station in Arzew. The flight software was uploaded to the on board computing suite and schedules for BUS system check out were loaded and run. The spacecraft was attitude stabilised using the on-board ADCS controller, allowing the deployment of the gravity gradient boom after only three days. The rest of the core systems on board were then tested and commissioned in the following days. Initial propulsion firing campaigns were started, in order to correct for launcher injection errors in readiness for joining spacecraft from the second launch. Payload commissioning was also carried out rapidly to ensure functionality. The result is a successfully working satellite that has survived launch in excellent condition. ALSAT-1 will become the first spacecraft to use IP protocols for all its routine operations in summer 2003.

12 ORBIT CORRECTION MANOUEVERS

Shortly after injection, it was found that ALSAT-1 had a higher Apogee than intended. This produced eccentricity in the orbit and caused the orbit LTAN to drift earlier than 10am, potentially causing imaging difficulties as the light budget was lowered. With the excellent in orbit results from the monopropellant Butane propulsion system, it was decided to corrections to the injection errors would be made. Approximately fifteen metres per second delta vee was expended over a four week period in March and April, reducing the apogee height by approximately fifty kilometres (Figure 13).

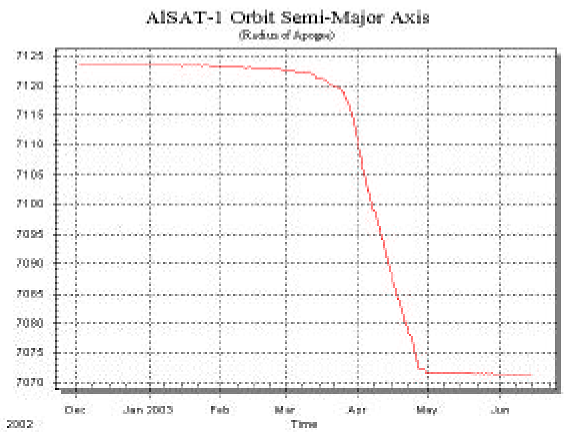

Figure 13 Results of Orbit Correction Manoeuvre

This correction, applied at perigee, circularised the orbit and reversed the LTAN drift to bring the orbit in line with that desired with the DMC. Further corrections can be made if necessary as a strategy is proposed to correct launch injection errors after the second launch if necessary.

13 FIRST RESULTS FROM ALSAT-1

As soon as the commissioning was complete and the spacecraft safe, the platform was prepared for a campaign of payload characterisation. This was soon started with early images showing great promise. The checkout of the payload was carried out in stages in order to progressively verify the various possible imaging parameters and modes. The size of the scenes returned has ranged from individual tiles to scenes that fully exercise both imagers and data recorders to the limit. Post processing systems have been refined to allow images to be stitched, and work is in progress refining the process for radiometric and geometric corrections. Within the first six months of operation, over 200 images have been captured, and the mission is operational as expected and being operated in a safe power and thermal regime. The RF budget is healthy to the 3.7m tracking ground station dishes and the data is quickly collected via the 8Mbps link. Imaging operations were suspended during the orbital correction period as errors were introduced into standard targeting procedures as the orbit parameters changed too quickly for the available Keplerian element sets to take account of the manoeuvres. Data sets from the on board GPS receiver were used to determine and propagate the changing orbit rapidly between sets of firings to allow accurate orbit models to be used for subsequent firings. The images generated by the multi-spectral imager payload on ALSAT-1 easily demonstrate the capability of the DMC spacecraft. Various full scenes have been returned, and one example is shown in Figure 32 covering 600x560km and the area of the western USA identified in Figure 17.

14 ALSAT-1 IMAGERY

Figure 14 Desert Irrigation from ALSAT-1

The image is pre-processed (level-0). A national users conference for ALSAT-1 is now planned in Algeria for May 2003. A significant challenge is the sheer amount of data that can be generated by the spacecraft, with 80x80km image tiles of 75Mbytes, and full scenes of up to 1Gbyte in size. Fast and reliable Internet links between the partner stations are crucial to meet the system goals.

Figure 15 Detail view of Ports of Los Angeles and Long Beach

Furthermore, the availability of data archiving systems that support a low cost COTS approach for the mission is a hindrance, and so the DMC consortium is investing in the development of its own system for image storage, distribution and delivery in the case of disaster imagery

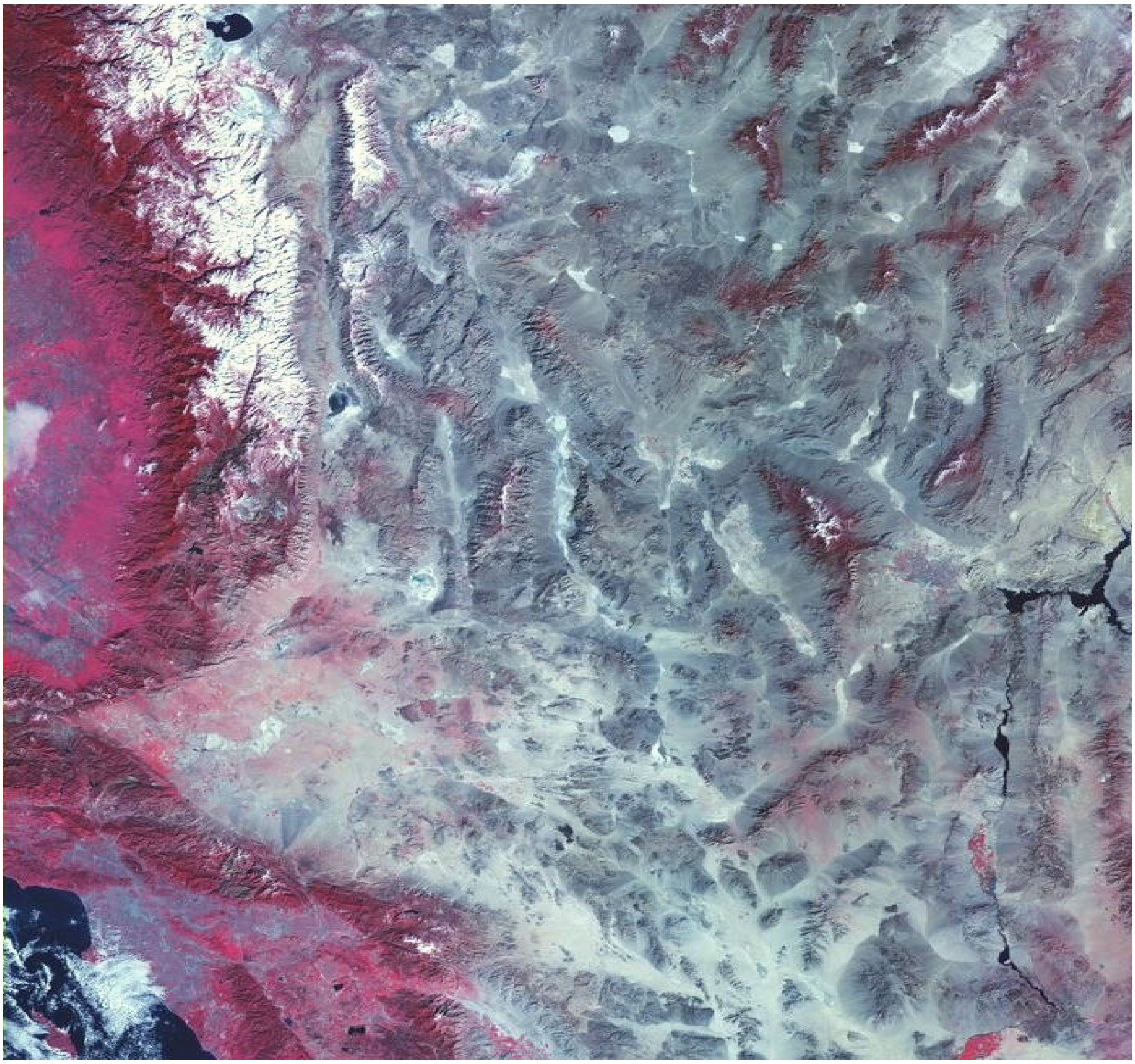

Figure 16 ALSAT-1 image of the Western United States (600x570km, 32m GSD, [NIR, R, G])

Figure 17 ALSAT-1 image location

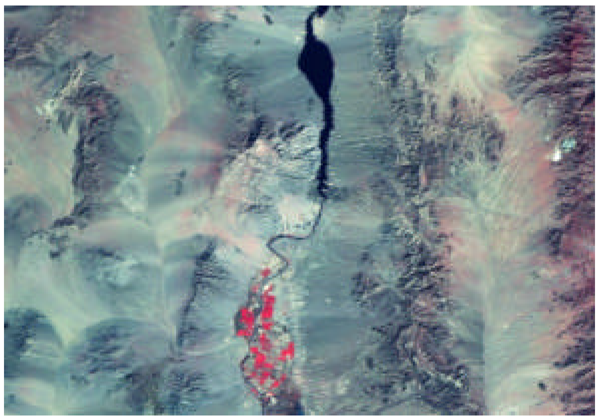

Figure 18 Colorado River and Lake Mohave in northwestern Arizona.

The primary SSDRs, when both filled simultaneously with image data from each imager bank can provide a huge image while still benefiting from detail at 32m GSD, as can be seen in Figure 16, with image detail in Figure 18, from the lower right hand portion of the image. SSTL has developed in house software to allow accurate recombination of the multi-spectral image bands over large areas and assist in the generation of image mosaics from a matched pair of full swath images or a sequence of windowed events to change the format of the images produced.

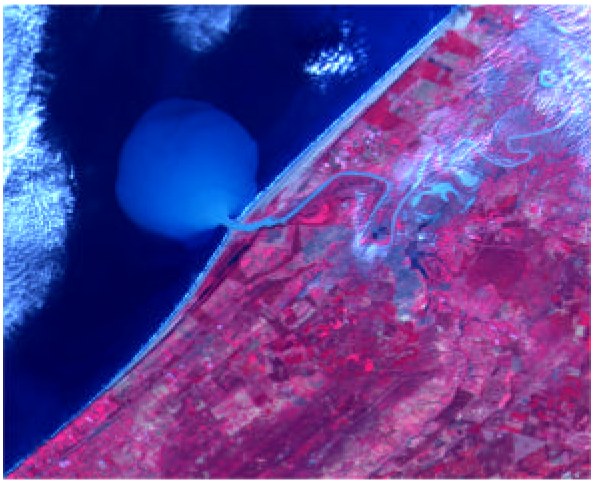

Figure 19 River discharge following flooding in Western Morocco, Jan 2003

Although complete coverage of the globe for disaster monitoring requires the full constellation, ALSAT-1 has already produced images of affected areas ahead of the DMC. Figure 19, showing the after effects of flooding in Morocco compares very favourably with NOAA data of the area.

15 PLANS FOR THE FUTURE

Work is ongoing in the implementation of a distributed product scheduling and data archiving system to support the DMC requirements.

CNTS are developing their capabilities with a planned purpose built facility for small satellite development and manufacture in Oran, Algeria. Continuing international co-operation and Know How Transfer and Training created during the ALSAT-1 programme will develop a respectable team and capability for Algeria.

The CNTS team with ALSAT-1 will continue research started on generating dynamic EO data for reference and repeat imagery for temporal coverage of specific regions in Algeria, with applications such as the monitoring of desertification and irrigation use. Such data products are also expected to revolutionise the use of medium resolution imagery in many areas, and commercial exploitation of such new data products will also be explored. Methods for improving the responsiveness of the system will also be investigated within the constellation, with Reuters "AlertNet" being a key user. The consortium anticipates that the DMC will be able to play a significant role in initiatives such as ESA's GMES, and in the international Disaster Monitoring Charter.

The CNTS team are planning to build and equip their new small satellite facility with full manufacturing and clean room facilities to allow the construction of core spacecraft modules for ALSAT-2, a proposed second Algerian national spacecraft to be realised the next few years, potentially being a higher resolution EO spacecraft. These modules would be based on the core systems from ALSAT-1, on which experience was gained during the Know How Transfer and Training programme. Again, this might form the anchor for a second international constellation with even greater capability and commercial potential. This would further the desire for continued know how transfer with CNTS reaping the benefits of expanding their knowledge base and the national space capability.

Plans are being finalised to operate the constellation as a co-ordinated unit, whilst maximising the owner knowledge, capability and control of the individual spacecraft. The Consortium is considering how the DMC can be maintained in the future, and is actively considering additional members to ensure continuity of data. Furthermore, constellations using different sensors are being considered at SSTL and by the international partners. Plans for high-resolution imaging missions with 4 and 2.5m Ground Sampling Distance are most mature [TOPSAT ref, [7]. Additional concepts include those for Thermal-IR hot-spot detection, Hyper-spectral and ocean colour imaging [6], and sea-state monitoring using radar altimetry.

16 CONCLUSION

Space is no longer the domain of the superpowers. The development of the ALSAT-1 and the Disaster Monitoring Constellation demonstrates that small satellites can involve a wide range of nations in worthwhile space programmes both nationally and internationally. Earth Observation missions are particularly well suited to stimulate the development of sustainable resource management and environmental monitoring. The DMC consortium model provides additional benefits, such as risk sharing and cooperation.

The Disaster Monitoring Constellation includes a number of innovations on different levels. It provides a practical realization of the need for dynamic Earth Observation, with daily imaging capability for any point on the globe. This is achieved through the formation of a novel international partnership, and enabled through small satellites in constellation. The DMC demonstrates how international collaboration can create operational space systems of which the whole is greater than the individual parts. Each partner gains benefits from others in the consortium. Yet each partner has an independent space asset to meet their own needs whilst benefiting from synergy through sharing of capacity with others. The model offers ideal opportunities for new space nations to become involved in space, and build up their national space industries.

Spacecraft such as the ALSAT-1 small Earth Observation platform are the ideal tool to be used within a constellation to provide higher temporal resolution than can be obtained from individual spacecraft. The ALSAT-1 and DMC payload implements a new way of addressing a wide swath from a small spacecraft, using very wide Field-Of-View sensors and electronic windowing, as opposed to a sophisticated attitude control system. As a result, the spacecraft cost is constrained, and novel imaging data products can be provided with exceptionally wide swath. This capability combined with an effective know how transfer and training programme has put Algeria firmly on the list of space nations and provided a framework for future national missions and international cooperation.

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